AGE AND GROWTH OF THE AMERICAN SHAD, FROM THREE ATLANTIC COAST RIVERS

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ABSTRACT

Study of age and rate of growth of the American Shad *(Alosa sapidissima)* in three southeastern coastal rivers (St. Johns River, Florida, Neuse River, North Carolina and Susquehanna River, Maryland) shows similar growth rate in these three streams and a body-scale relationship that can be described by the parabolic equation, $y = 22.58x^2 + 34.96x + 0.41$. When allowance is made for differences in aging methods, it appears that growth was similar to that reported in the literature for shad from two Canadian populations. Little difference was found in length of males and females of the same age but males matured earlier and were generally more abundant in commercial catches. The annulus appears to be a true year-mark on scales of shad spawning for the first time and results from aging of these fish from scales are not in conflict with known facts about the shad. Spawning marks are considered to be year-marks for "repeater" shad, that is, shad that have spawned more than once, but this has not been validated.

INTRODUCTION

Production of shad *(Alosa sapidissima)* along the Atlantic coast has declined sharply since 1896. At that time, the catch was 50 million pounds as compared to 17 million pounds in 1946 and 8 million pounds in 1950. In 1950, the U. S. Fish and Wildlife Service began an Atlantic-coast shad investigation initiated by the Atlantic States Marine Fisheries Commission. The purposes of this investigation are to determine the causes of the decline of shad since the turn of the century and to suggest measures for the restoration of the shad populations to their former levels of abundance. The ultimate objective is the suggestion of management measures for maximum sustained yields from each population.

This paper is concerned with age and growth of shad from the St. Johns River, Florida; the Neuse River, North Carolina; and the Susquehanna River, Maryland and with the validation of the annulus as a true year mark for shad.

Leim (1924) studied age and rate of growth of shad as part of life history studies of this species in Canadian waters. He determined age from counts of annuli on scales. Borodin (1925) counted the transverse grooves

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on the scales and divided by two to determine age in years. Barney (1925) confirmed Borodin's method by the study of otoliths. Greely (1937) questioned Borodin's method. His annuli counts agreed closely with those of Leim. Cating (1953) used annuli to determine age and separated true from false annuli, to the fourth annulus, by a method of transverse groove counts. By using easily-read scales, he found that the number of transverse grooves within each annulus was quite constant in all fish examined.

American shad are anadromous and spawn during late winter (February-March) in the St. Johns River and in the spring (April-May) in the Neuse and Susquehanna Rivers. The young-of-the-year fish remain in fresh or brackish water until fall (October-November) when they migrate to the sea. Here they stay from two to five years before returning to fresh water to spawn for the first time.

Prior to the initial spawning run, true annuli are formed each year on shad scales. During the initial and subsequent runs, spawning marks are formed. These marks probably are true year marks (Cating, 1953) but differ in form from the pre-spawning annuli. In the present paper annuli are denoted by Roman numerals, and spawning marks by Arabic numerals. Since all adult shad were caught during the spawning season, the edge of the scale was designated as the location of a spawning mark. Age class of a shad is denoted by two numerals (an age-class III-1 shad has 3 true annuli and one spawning mark and is approximately 4 years of age).

A shad that has spawned more than once is termed a "repeater." An examination of scales indicates there are few "repeaters" in the rivers investigated south of Chesapeake Bay. No repeaters were taken from the St. Johns River, Florida and repeaters made up less than 3 percent of the sample from the Neuse River, North Carolina, but were 37 percent of the sample from the Susquehannna River, Maryland. Since growth could not be calculated from scales of repeaters, because there was considerable resorption of the scale edge during the spawning run, only scales from "non-repeater" fish were used in this study and conclusions concerning growth apply only to such fish.

Methods of Investigation

COLLECTION OF MATERIAL

Scales and data from 2038 adult and 164 immature shad collected during investigations on the St. Johns, Neuse, and Susquehanna Rivers, were available at the Beaufort laboratory. The St. Johns River sample was taken by gill nets and haul seines. The Neuse and Susquehanna River samples were taken by gill nets and pound nets. Immature shad were caught by a surface trawl similar to that described by Massmann, Ladd, and McCutcheon (1952). The commercial gill nets used had mesh of 5- to 6-inch stretch measure and therefore selected the larger fish although some small fish were also caught. Pound nets and haul seines, with smaller mesh, ranging from

2- to 3-inches stretch measure, were less selective. Since part of the collection from each of the rivers was taken by haul seines and pound nets, it is assumed that the composite samples for each river contain fish from all age classes present.

Fork-length measurement to the nearest tenth of an inch, weight to the nearest tenth of a pound, and sex were determined for each fish. To facilitate accurate measurement, scales were taken from the left side of the fish in an area below the insertion of the dorsal fin and at about one half the body depth. In this area on shad most scales are symmetrical.

PREPARATION AND EXAMINATION OF SCALES

Scales of shad are not imbedded tightly and are easily lost. Many of those in the samples were of the regenerate type. Such scales and those showing resorption at their edges were discarded. Plastic impressions of 2 scales used for the growth study were read twice; the first reading to determine age and the second to check age and mark the positions of the focus and annuli on strips of paper. A nomograph (Carlander and Smith, 1944) was used to determine the fork length of the fish at the time of annulus formation.

Body-Scale Relationship

The body-scale relationship was determined from a sample of 615 adult and 164 immature shad taken from the three rivers. An examination of the variation in the relationship between body length and scale radius length by sex for samples from each river revealed only small differences. Inspection of the original data, after plotting length of scale radius (y) against fork length (x), (Figure 1), showed that the body-scale relationship was such that it could be described approximately by the parabolic equation $y = ax^2 + bx + c$; which when fitted to the data on body length of scale radius, has the following value: $y = 22.58x^2 + 34.96x + 0.41$.

Age and Growth of Shad

AGE-CLASS DISTRIBUTION

Age-class distribution of 1691 shad taken in commercial catches from the St. Johns, Neuse, and Susquehanna Rivers is shown in Table 1. Differences in age-class distribution by sex in each river indicates general earlier maturity of the males. Although a few 2-year-old males have been captured in streams, presumably on their first spawning run, most of the male first-spawners were 3 years old in the St. Johns River and 4 years old in the Neuse and Susquehanna Rivers. A few females spawned first at 3 years of age, but the majority of them spawned first at 4 and 5 years of age. Shad between 6 months and 2 years of age were not available for this study because shad of these ages were at sea and not present in the rivers.

TABLE 1.—*Percentage of non-repeater shad by sex and age class from the St. Johns, Neuse, and Susquehanna Rivers.*

Age class	St. Johns		Neuse		Susquehanna	
	Male	Female	Male	Female	Male	Female
I-1					9	
II-1	61	5	16	1	5	
III-1	33	29	58	25	60	44
IV-1	6	56	26	44	21	46
V-1		10		28	5	10
VI-1				2		
Total number	193	487	400	289	92	230

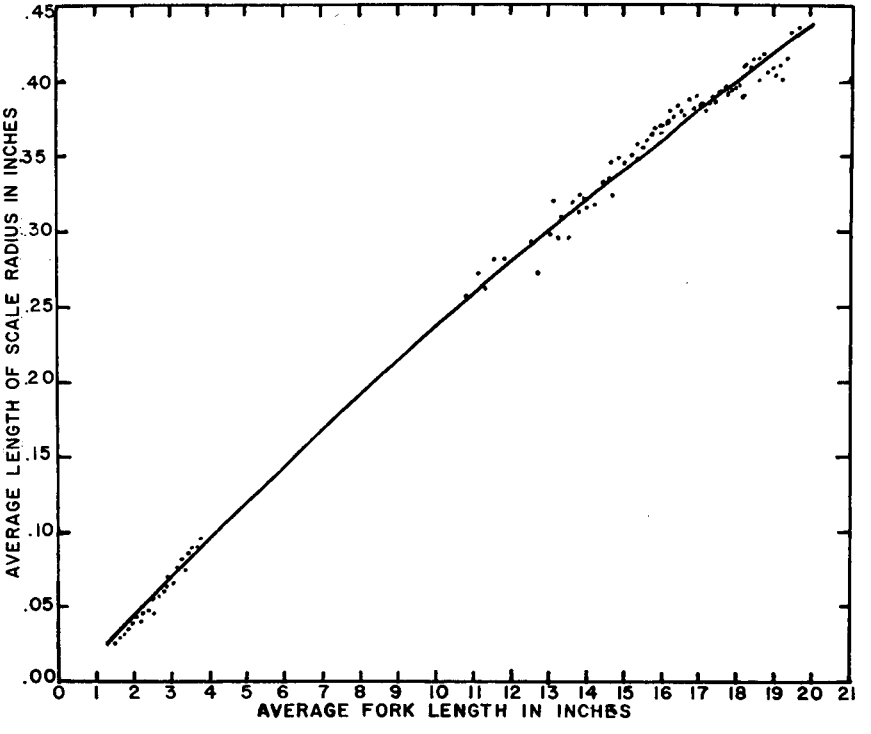

FIGURE 1.—The body-scale relationship of American shad from three southeastern rivers using curvilinear regression line.

GROWTH OF SHAD

Two shad of each sex were selected from each river by 0.1 inch size class for growth determination. Of the 1691 shad in the samples 431 were selected by this method. Female shad had a slightly faster rate of growth than males, but the difference in length between males and females of the same age class was not large. Figure 2 shows graphically differences in average growth rate and growth increment for 164 male and female shad from the Neuse River. At 4 years of age (age class III-1) females from the St. Johns River were calculated to be 0.6 of an inch longer than the males. Females from the Neuse River were 0.3 inch longer, and from the Susquehanna River 1.1 inches longer than the males (Table 2).

The relationship between fork length and total length of shad was determined so that the growth rates calculated in this study could be compared with those of other studies. Total and fork-length measurements were available[2] from 98 shad ranging in length from 15 to 22 inches. The average conversion factor for total to fork length was 0.894. This conversion factor may be subject to a small error for shad less than 15.0 inches in length.

Leim (1924, Figure 37) illustrates a scale from one of four 2-year-old shad from 6.3 to 7.8 inches fork length.[3] By using the nomograph previously mentioned, the first annulus (fresh-water mark) was calculated to have been formed when the fish was between 3.2 and 3.8 inches fork length; the second annulus between 5.4 and 6.5 inches fork length. Hammer[4] shows that the first ring (fresh-water mark) is formed when the shad leaves fresh water in the autumn of its first year. Therefore, the fresh-water mark is not a true annulus. He used 362 adult shad from the Susquehanna River to calculate the length of juveniles at the formation of the fresh-water ring. The mean of these calculated lengths was 3.6 inches.[5] This compares closely with the calculated length at the first annulus of Leim's Figure 37 (3.2 to 3.8 inches). By comparing Cating's Figure 3 (1953) with Leim's Figure 37 it can be seen that the scale in Figure 3 is similar to the area enclosed by the first ring in Figure 37. Figure 3 is of a scale from a 4- or 5-months old shad captured in fresh water. Smith (1899) says, "When 2-months-old, shad are about 2 inches long; having attained this size, they add about an inch to their length in from 2½ to 3½ months, so that when they leave the fresh water in the fall they are from 3½ to 4 inches long." The foregoing observations indicate that Leim was calling the fresh-water mark the first

[2]Unpublished data, U. S. Fishery Laboratory, Beaufort, N. C.

[3]The total length in centimeters of Leim (1924) was changed to fork length in inches by converting total length to inches and multiplying by the conversion factor 0.894.

[4]Hammer, Ralph Curtis, 1942. The homing instinct of the Chesapeake shad, *Alosa sapidissima* Wilson, as revealed by a study of their scales. Thesis, University of Maryland (typewritten).

[5]Total length in half-centimeters of Hammer (1942) was changed to fork length in inches.

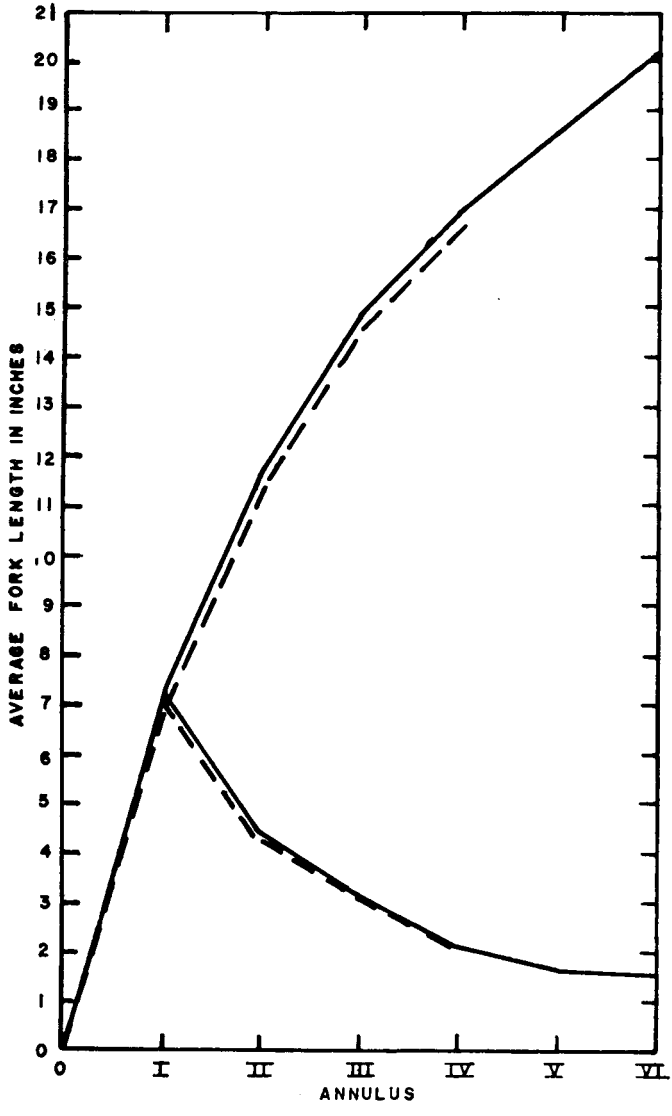

FIGURE 2.—Average calculated fork length at each annulus and average annual increment of male (broken line) and female shad (solid line) from Neuse River.

annulus, thus causing a difference of one year between his age determinations and those in this study.

Material from the St. Johns, Neuse, and Susquehanna Rivers considered in this report was compared to Leim's (1924) growth study of 5-year-old shad from Scotsman Bay, Nova Scotia, in 1920 (Table 2). The calculated lengths in his study agreed quite closely with those of the samples from the three United States rivers after correction for the one year difference in age determination.

Validity of the Annulus of Shad Scales as a Year Mark

Heretofore, no attempt has been made to validate the annulus on shad scales as the true year mark. The following three criteria of validation, similar to those suggested by Hile (1941), were applied.

1. *Modes in the length-frequency distribution of the sample should coincide with the mean calculated lengths of age groups based on scale reading.* When this method is applicable, it is usually adequate only for fish which are four years of age or younger (Rounsefell and Everhart, 1953). Two thousand thirty-eight specimens were used to find the length-frequency distributions of shad in the three rivers (Table 3). The means of the calculated fork lengths at annulus III and IV of males from the St. Johns and Neuse Rivers (Table 4) agree closely with the modes in the length-frequency

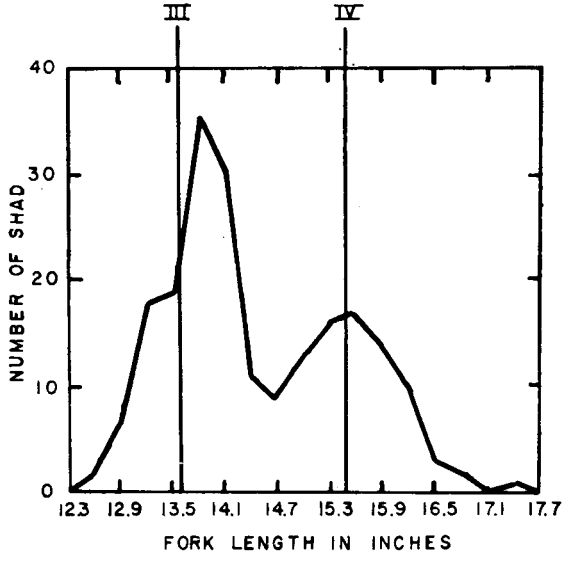

FIGURE 3.—Length-frequency distribution of 208 St. Johns River shad (males) compared with mean calculated lengths at annuli III and IV.

TABLE 2.—*Average calculated fork lengths in inches at each annulus for shad from samples taken from several populations along the Atlantic coast.*

River	I		II		III		IV		V		VI	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
St. Johns	6.9	7.1	10.9	11.2	13.6	13.9	15.5	16.1	—	17.6	—	—
Neuse	7.0	7.2	11.3	11.6	14.5	14.8	16.6	16.9	—	18.6	—	20.2
Susquehanna	6.5	6.9	10.5	11.2	13.0	14.2	14.8	15.9	15.9	17.5	—	—
Scotsman Bay 1920[1]	7.1	7.6	10.3	11.2	12.9	13.9	15.3	16.4	—	—	—	—

[1]After Leim (1924) with adjustment as described in text.

distributions (Figures 3 and 4). There were too few age-class II-1 female shad in the samples from the three rivers and in the male sample from the Susquehanna River to make modes in the length-frequency distributions (Table 3, footnotes). Also, there were no modes in the length-frequency distributions for age-class III-1 and IV-1 females from all three rivers and males from the Susquehanna River probably because of the overlap in lengths of shad in these two age classes. Therefore, this test could be used only for male shad from the St. Johns and Neuse Rivers.

TABLE 3.—*Length-frequency distribution of shad from the St. Johns, Neuse, and Susquehanna Rivers.*

Fork-length (inches)	St. Johns		Neuse		Susquehanna	
	Males	Females	Males	Females	Males	Females
10.4-10.6					1	
10.7-10.9					2	
11.0-11.2					1	
11.3-11.5					4	
11.6-11.8					1	
11.9-12.1						
12.2-12.4						
12.5-12.7	2				2[1]	
12.8-13.0	7				1	
13.1-13.3	18	1	3			
13.4-13.6	19	1	7			
13.7-13.9	36[1]	2	7			
14.0-14.2	30	3	13[1]			
14.3-14.5	11	7[1]	20		3	
14.6-14.8	9	10	15		5	
14.9-15.1	13	15	16		4	
15.2-15.4	16	20	8		7[2]	
15.5-15.7	17[2]	18	17	1	20	
15.8-16.0	14	31[2]	47	1[1]	42	
16.1-16.3	10	37	60[2]	1	31	4
16.4-16.6	3[3]	58	89	2	31[3]	5
16.7-16.9	2	82	70	5	24	12[2]
17.0-17.2		74	45	10[2]	21	28
17.3-17.5	1	67[3]	20	22	25	47
17.6-17.8		41	11	32	7	35
17.9-18.1		27	6[3]	51	3	56[3]
18.2-18.4		11	3	36[3]		32
18.5-18.7		7		45		35
18.8-19.0		7		39		18
19.1-19.3		1		32		6
19.4-19.6			1	25		9
19.7-19.9				7		2
20.0-20.2				5		3
20.3-20.5				4		1
20.6-20.8				3		1
20.9-21.1				1		
21.2-21.4						1
Totals	208	520	458	322	235	295

[1] Mean fork length at age class II-1.
[2] Mean fork length at age class III-1.
[3] Mean fork length at age class IV-1.

2. *There should be a regular increase in fish length with each succeeding annulus.* Such an increase is noted in successive age groups for both sexes in the samples from each river (Table 4).

3. *There should be a close agreement between average calculated length of a fish at any annulus and the average actual length of the fish of the*

TABLE 4.—*Average fork length at capture and average calculated fork length at each annulus of shad from St. Johns, Neuse and Susquehanna Rivers—expressed as inches.*

River and item	Number specimens	Age class	Sex	Length at capture	Annulus 1	2	3	4	5	6
St. Johns	36	II-1	M	13.7	6.9	11.0				
	14	II-1	F	14.4	6.9	11.3				
	31	III-1	M	15.5	6.9	10.8	13.6			
	33	III-1	F	15.8	7.1	11.0	13.8			
	7	IV-1	M	16.5	6.8	10.7	13.4	15.5		
	24	IV-1	F	17.3	7.1	11.2	14.1	16.1		
	18	V-1	F	18.6	7.4	11.3	14.1	16.1	17.6	
Total and grand average lengths	74	—	M	—	6.9	10.9	13.6	15.5		
	89	—	F	—	7.1	11.2	13.9	16.1	17.6	
Neuse	34	II-1	M	14.2	6.9	11.0				
	2	II-1	F	15.8	6.5	12.2				
	44	III-1	M	16.3	7.1	11.5	14.4			
	19	III-1	F	17.1	6.8	11.6	14.9			
	9	IV-1	M	18.0	7.2	11.7	14.7	16.6		
	24	IV-1	F	18.3	7.1	11.5	14.6	16.9		
	27	V-1	F	19.5	7.6	11.6	14.7	16.8	18.6	
	5	VI-1	F	20.5	7.8	11.9	15.5	17.7	18.9	20.2
Total and grand average lengths	87	—	M	—	7.0	11.3	14.5	16.6		
	77	—	F	—	7.2	11.6	14.8	16.9	18.6	20.2
Susquehanna	6	I-1	M	11.1	6.7					
	4	II-1	M	12.5	6.1	10.2				
	19	III-1	M	15.2	6.7	10.8	13.3			
	20	III-1	F	16.9	6.9	11.3	14.4			
	17	IV-1	M	16.6	6.3	10.2	12.7	14.9		
	22	IV-1	F	17.9	6.8	11.3	14.2	16.1		
	4	V-1	M	17.0	6.8	10.4	12.7	14.4	15.9	
	12	V-1	F	19.3	7.0	10.9	13.8	15.6	17.5	
Total and grand average lengths	50	—	M	—	6.5	10.5	13.0	14.8	15.9	
	54	—	F	—	6.9	11.2	14.2	15.9	17.5	

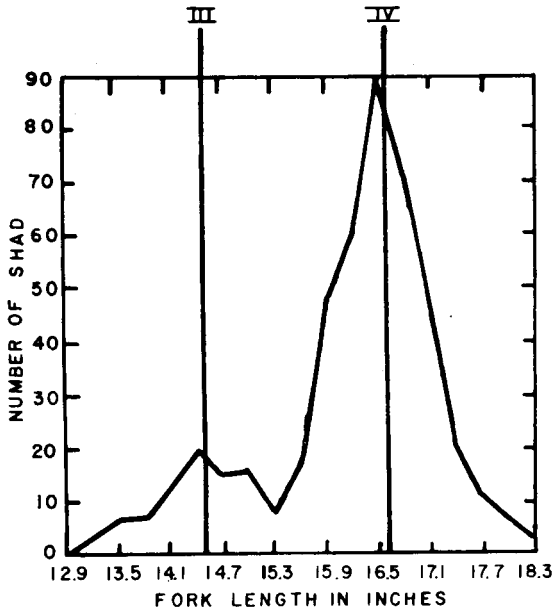

FIGURE 4.—Length-frequency distribution of 458 Neuse River shad (males) compared with mean calculated lengths at annuli III and IV.

corresponding age group at the time of capture. In all but two instances, there is fairly close agreement between actual length at capture and calculated length (Table 4). The calculated length at any annulus is closer to the actual length at capture than to any other age class. The two exceptions to this last statement are: The fork length at annulus V in Susquehanna River males and the fork length at annulus VI in Neuse River females. These samples probably were too small to calculate the average fork lengths accurately.

The first criterion was applicable to the males only from the St. Johns and Neuse Rivers. The second and third suited samples of both males and females from all three rivers. By the three preceding criteria it appears that results from aging shad from scale annuli are not in conflict with known facts about the shad and its life history.

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